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On-line measurements of soot aggregates in a near-traffic urban environment – with applications to surface area and lung dose estimations

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In traffic-dense urban environments, soot (black carbon) is often dominating the emissions by mass. The soot cores carry different degrees of coatings. As soon as the particles are emitted to the atmosphere, the atmospheric processing begins. When estimating exposure, or dose to the lung, with respect to surface area or mass from mobility number size distributions, information about the particle shape and effective density are needed.

In this study two on-line instruments; a DMA-aerosol particles mass analyzer (DMA-APM; Park et al., 2003) and an aerosol mass spectrometer equipped with a laser vaporiser for soot detection (SP-AMS, Onasch et al., 2012), was brought to a traffic-dense urban environment (Central Copenhagen). Complementary measurements were also performed at a rural background site nearby. From the DMA-APM data the effective density was determined, defined as:

$$\rho_{\text{eff}}(d_m) = \frac{6m}{\pi d_m^3}$$

where $d_m$ is mobility diameter. From the data the lung deposited particle mass and surface area was estimated (as described in Rissler et al., 2012) and the results compared to that when assuming spherical particles.

The measurement showed that the particles found at street level were externally mixed, with one group of dense particles with effective density $\sim 1.4 \text{ g/cm}^3$, and one group of highly aggregated particles, mainly soot (confirmed by electron microscopy). The aggregates had the typical behavior of decreasing effective densities with size, ranging from 0.94 g/cm$^3$ for 50 nm particles down to 0.26 g/cm$^3$ for 400 nm (Figure 1). The particle effective densities found at the street level were almost identical to those found for freshly emitted diesel particles generated under well controlled lab-conditions (Park et al., 2003; Rissler et al., 2013), with no signs of atmospheric aging under winter conditions (January-February), and well described by a power law function as a function of size.

Whereas the particle effective densities were stable over time, the relative number fraction of the two types of particles varied considerably. Two types of time variations were observed; that over time of day, and that depending on the air mass origin. The diurnal variation in agglomerated soot particle concentration was associated with the traffic pattern – showing the lowest concentrations at night (00:00-04:00). The fraction of “dense” particles increased during occasions with trajectories from polluted areas. Thus, these particles were likely dominated by long range transport, while the aggregated soot particles were from local sources. This hypothesis was further supported by the measurements at the rural background site.

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![Figure 1. Examples of measured density spectra for particles of a diameter of a) 75 nm, b) 150 nm and c) 250 nm, illustrating the particle external mixture during two periods – one period under with major influence of long range transport (black line) and one period with the fresh emissions superimposed in a very clean background (grey dashed curve). The spectra are raw APM spectra, normalized with respect to frequency of the soot mode.](image-url)